A Synopsis

Lunar Strategic Roadmap Committee

Meeting #1

January 24-25, 2005

Space Center Houston

Lunar Exploration Strategic Roadmapping Team

Members

Rear Admiral Craig E. Steidle, USN (Ret.), co-chair, NASA HQ
William F. Readdy, co-chair, NASA HQ
General Jefferson D. Howell Jr., USMC (Ret.), co-chair, NASA HQ
Lieutenant General Thomas P. Stafford, co-chair, USAF (Ret.)

Bruce Abbott, USN/NRO
Joseph Charyk, COMSAT president (ret.)
Dr. Michael Duke, Colorado School of Mines
Mike Hawes, NASA Headquarters
Dr. James Head, Brown University
Milt Heflin, NASA, Johnson Space Center
Dr. Howard McCurdy, American University
Dr. Thomas Morgan, NASA Headquarters
Dr. Firouz Naderi, JPL
Dr. Brad Parkinson, Stanford University
Dr. Donald Pettit, NASA, Johnson Space Center
Mr. Robert Edwin Smylie, Universities Space Research Association (USRA)
Dr. Paul Spudis, Applied Physics Lab (APL) Johns Hopkins University
Tom Tate, HR Committee on Science and Technology (retired)
Dr. Geoff Taylor, University of Hawaii
Dr. Brenda Ward, NASA, Johnson Space Center

From the President's Directive:

Conduct human exploration to Mars after

1. Acquiring adequate knowledge about the planet using robotic missions, and after
2. Successfully demonstrating **sustained** **human exploration missions to the Moon.**

Key Questions

Posed at the Meeting

1. What is the definition of **"Sustained"** exploration as applied to the Moon (**e.g., Moon to stay or Moon as a stepping stone**)?
2. How long a stay on the lunar surface is required to demonstrate Mars adaptation and operations?
   - How should terrestrial analogs be used in conjunction with lunar activities?
   - How should ISS be used?
   - What needs to be demonstrated at Mars?
3. How should NASA transition from a lunar focus to a Mars focus once lunar objectives are achieved?
4. How do we build in a transition strategy from the beginning, particularly for commercial interests?

Lunar Exploration Analysis Group (LEAG)

G. Jeffrey Taylor
University of Hawaii

Goals for First Meeting

(Meeting Held January 10-12, 2005)

Analyze two important questions:

1. What will humans do on the Moon when they get there?
2. What are the priorities and phasing for human precursor investigations and technology

Major Findings

- Assumption: **sustained** human presence on the Moon is essential for a dynamic program of robotic and human exploration of the solar system

- Strong consensus that lunar program should lead to **continuing** expansion of human capabilities on the Moon
  - Learn how to live and work on another planet, essential for the human exploration of Mars and beyond
  - Allows for increasing involvement of private sector as capabilities of transportation system and lunar facility increase

Single Site -- for a Permanent Stay

- Strong consensus that program should focus on one locality that serves as a focal point for human exploration
- Advantages of single site:
  - Leads to incremental growth of the facility and its capabilities
  - **Opens the way for a permanent facility that allows permanent habitation**
  - Its evolutionary development and long-term operation require developing capabilities for self-sustaining operation (e.g., ISRU, closed system life support)
  - Develops capabilities for doing long-duration missions to Mars and beyond
  - Lends itself to developing a strategy for transition from government to private operation
  - **Becomes an off-Earth village in public perception**

Disadvantages of single site

- **Danger of bureaucratic fixation of big lunar base and then maintaining it without end.**

- Mitigated by
  - Involvement with private industry from the start
  - A strategy to transition to non-NASA operation
  - Plans to lease facilities to or from private enterprises

Robotic Measurements, Experiments, and Other Activities

- Elements of robotic missions--higher priority
  - **Resource assessment (prospecting, esp. polar regions)**
  - **Experiments on regolith excavation and handling**
  - **Experiments in resource extraction and storage**
  - **Biology experiments**
  - **Baseline scientific characterization (before extensive contaminated or altered)**
    - Lunar atmosphere characterization
    - Read the scientific record of the polar volatile deposits
  - **Emplacement of infrastructure elements**
    - Modest at first (comm/nav, landing beacon)
    - Increasingly more complex with time

Other Important Matters

- Need for private involvement from the start, including on robotic missions. (Not enough discussion to know if this is a consensus view.) Possibilities:
  - Prizes
  - Data purchases
  - NASA-industry partnerships on instrument or ISRU experiment

Architecture for Lunar Expedition

Exploration Systems Spiral Objectives

Spiral 1 (2008-2014)

- Provide precursor robotic exploration of the lunar environment
- Deliver a lunar capable human transportation system for test and checkout in low Earth orbit

Spiral 2 (2015-2020)

- Execute extended duration human lunar exploration missions
- Extend precursor robotic exploration of the Mars environment

Spiral 3 (2020-TBD)

- Execute a long-duration human lunar exploration campaign using the moon as a testbed to demonstrate systems (e.g., Lander, habitation, surface power) for future deployment at Mars

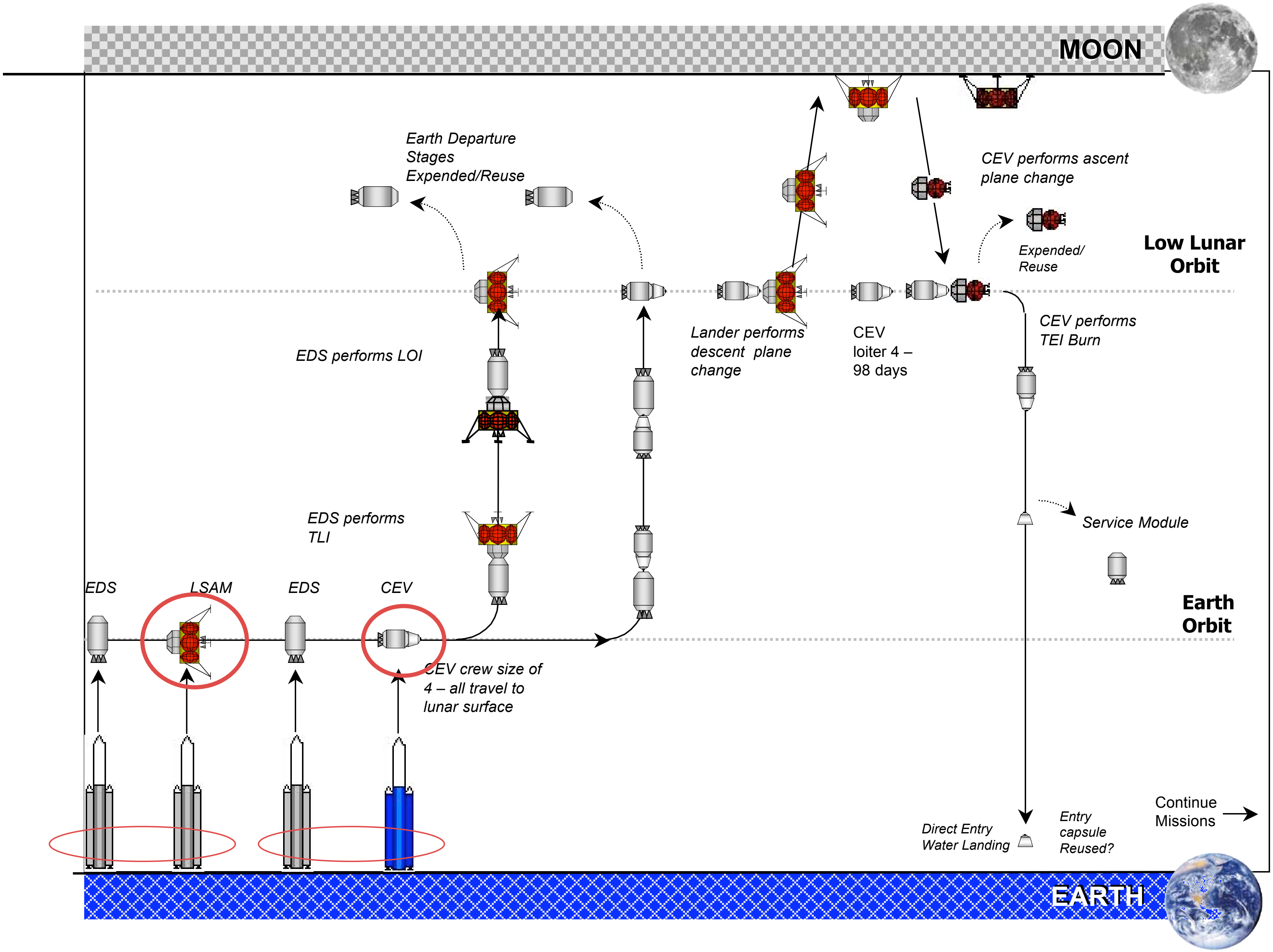
Spiral 4 (~2025-TBD)

- Execute human exploration missions to the vicinity of Mars

Spiral 5 (~2030-TBD)

- Execute initial human Mars surface exploration missions

POD- Lunar Trade Architecture



Lunar Roadmap Alternatives

- **Presenting 4 roadmap alternatives for committee to consider**
  - Evolution Emphasis
  - Early Outpost
  - Expedited Moon-to-Mars
  - Commercial Emphasis
- **Exercise for committee**
  - Review and edit presented set of roadmap alternatives
  - Eliminate from *or* add to set of roadmap alternatives

Option A: Evolution Emphasis

2010-2015 | 2015-2020 | 2020-2025 | 2025-2030

- Decision to emplace far side astronomy instruments
- Other high value science or security interests at alternate sites

Global Sorties

Robotic Missions

Spiral 2
Sortie Missions

Spiral 3
Single Location Outpost

Spiral 3′
Single Location Base

- High science value site (discovery)
- High concentration resource site located
- Mars date imperative
- Political Imperative
- Security Imperative

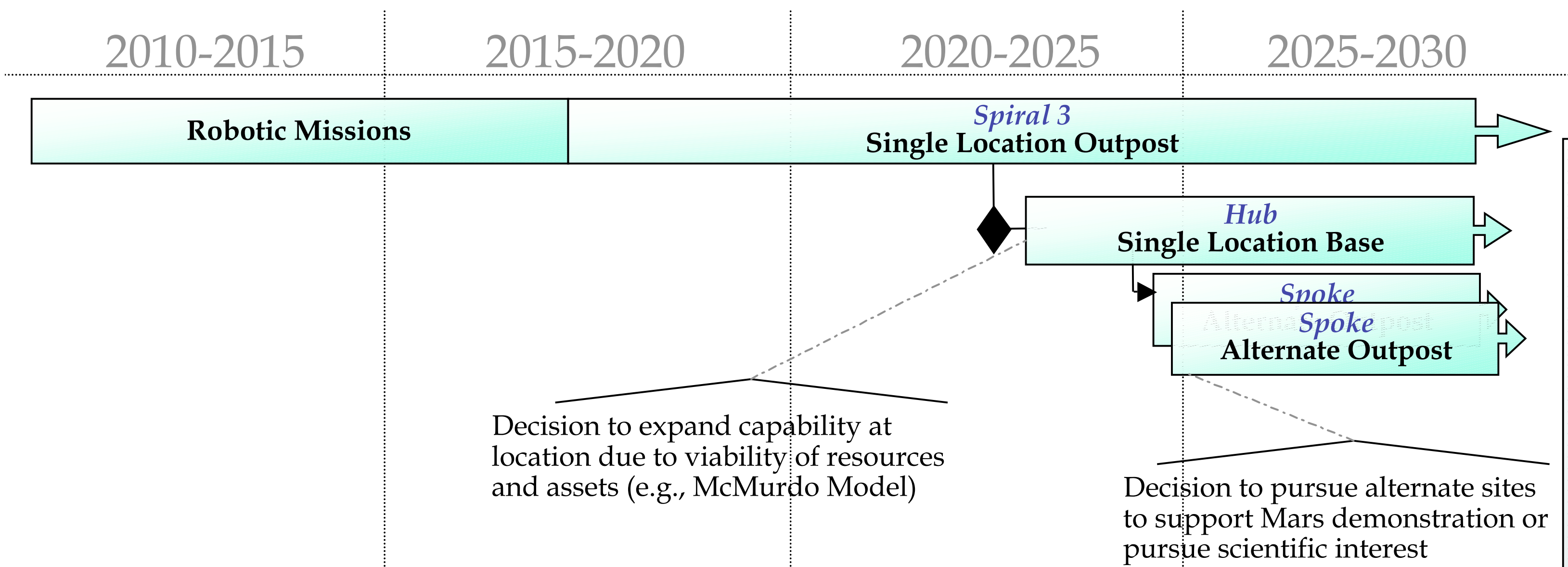
- Decision to perform Long full-up Mars simulation

	2010-2015	2015-2020	2020-2025	2025-2030
Objectives		• Outpost location verification • Transportation system demonstration/verification • Resource characterization & utilization demonstration • Science: Apollo class; sample return	• Demonstrate longer duration operations and habitability (Mars short stay) • In-depth scientific investigations (eg: deep drilling) • Initial incorporation of in situ resources into missions (eg: life support , fuel cells…) • Achieve some degree of self-sufficiency	• Demonstrate long Mars stay surface mission • Systems verification exercise • Mars crew down-select • In-depth scientific investigations • Use of in situ resources to enhance logistics
Description		• Potential global access • Duration: 4-14 days • Surface mobility: up to 10 km • Expendable surface infrastructure	• Intermittent visits • Duration: 30-90 days • Surface mobility: 10s of km • Reusable surface infrastructure	• Up to two visits • Duration: 365 days or greater • Surface mobility: 10s of km • Reusable surface infrastructure

Transition Options:

- Decommission the base and focus on Mars exploration
- Pursue global sorties in parallel with Mars exploration
- Sustain Base (and access to) at appropriate level to support science and security needs

Option B: Early Outpost



Transition Options:

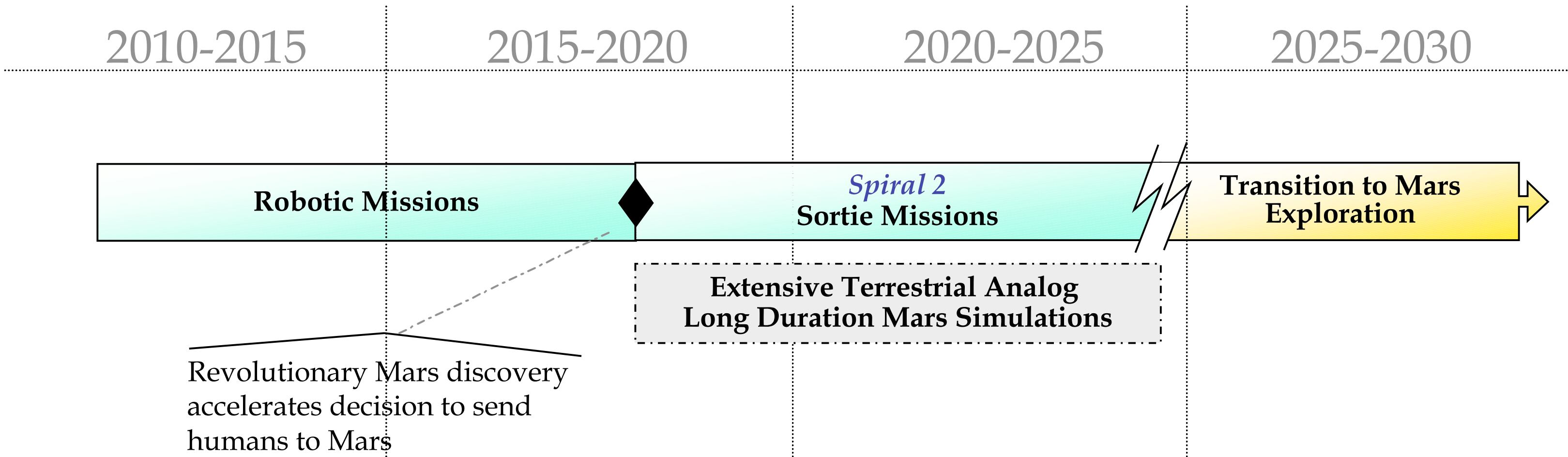
- Decommission infrastructure supporting Mars simulations
- Sustain alternate capability while pursuing Mars exploration

	2010-2015	2015-2020	2020-2025	2025-2030

Objectives	• Outpost location verification
	• Transportation system demo/verification
	• Resource characterization & utilization demonstration
	• Science: Apollo class; sample return
			• Demonstrate longer duration operations and habitability (Mars short stay)
			• In-depth scientific investigations (eg, deep drilling)
			• Initial incorporation of in situ resources into missions (eg, life support, fuel cells…)
			• Achieve some degree of self-sufficiency
				• Hub objective: Infrastructure enables alternate outposts
				  • Viable resource utilization for surface transportation or
				  • Availability of nuclear power

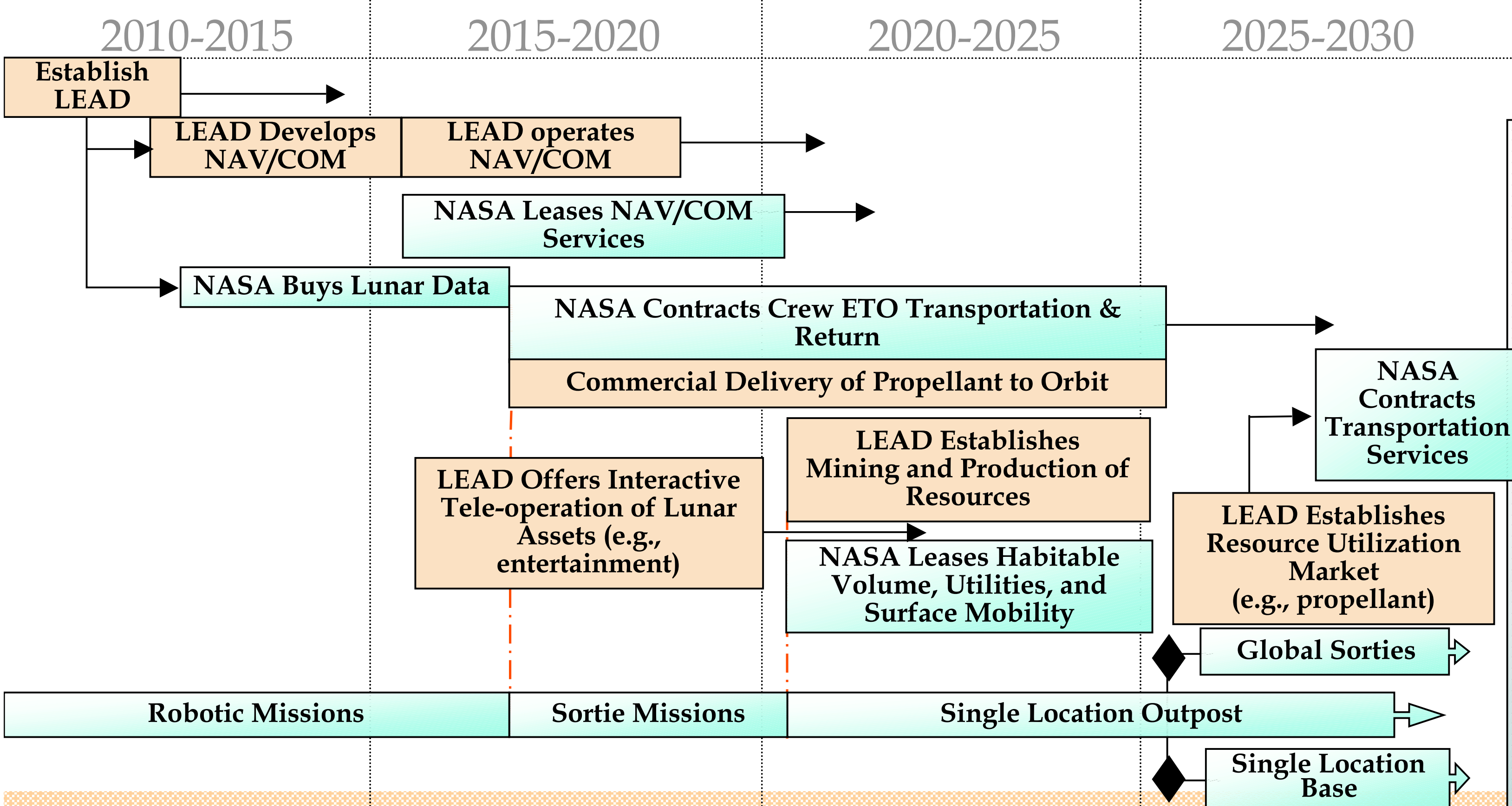
Description	• Robotic Mission Set		• Intermittent visits • Duration: 30-90 days • Surface mobility: 10s of km • Reusable surface infrastructure	• Hub used for logistics / safe haven, transportation and resources focal point • Alternate outpost used for Mars demonstrations, facility support for specialized science • Extended exploration range

Option C: Expedited Moon-to-Mars



	2010-2015	2015-2020	2020-2025	2025-2030
Objectives			• Demonstrate operational readiness beyond LEO capabilities (ie: Gemini of Apollo) • Opportunistic Lunar Science • Extensive system test and crew experience performed at terrestrial analog (in the interest of time and funding)	• Abandon human lunar presence • Abandon program elements not applicable to Mars • NASA capability transitions to Mars Exploration
Description			• Less than 5 missions • Duration: 4-14 days • Location independent • Expendable Infrastructure	• Transition from Lunar to Mars only human missions

Option D: Commercial Emphasis



Transition Options:

- Broad customer base enabled
- NASA uses Moon as required through commercial entity
- NASA capabilities focused on Mars

LEAD = Lunar Exploration And Development Authority

Obj.

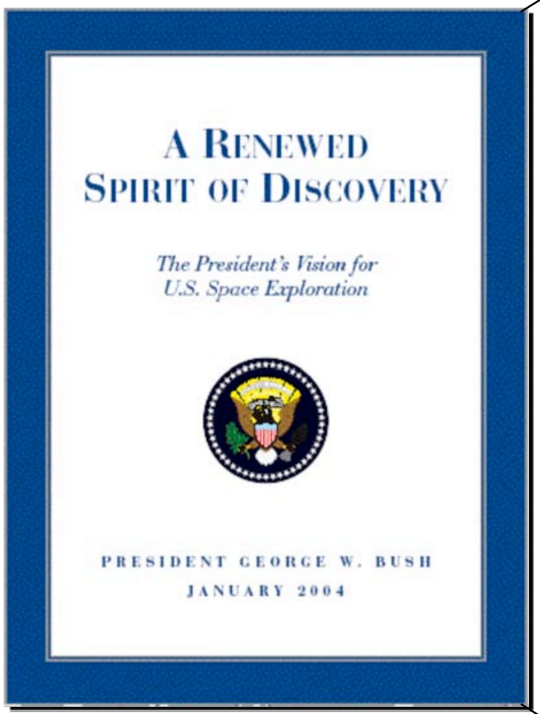
- LEAD objective is to open Space to enterprise, markets and ultimately sustained autonomous, self-supporting activities a similar institutional innovation is required to assure early industrial, private and international market involvement, in analogy to the East India Company of ages past and of Comsat/Intelsat of the Space Age

Description

- NASA/LEAD develops/provides "additive cost" access rights to any and all infrastructure components
- NASA/US GOV indemnifies for 2010 through 2030 period. The users will pay an insurance premium to LEAD for such and related insurance issues;
- NASA/LEAD enters into long-term co-operation/procurement contracts (services, hardware, RDT&E)
- Private Sector partners have exclusive rights to any intellectual/other property rights
- NASA/LEAD will phase out where Private sector can take over

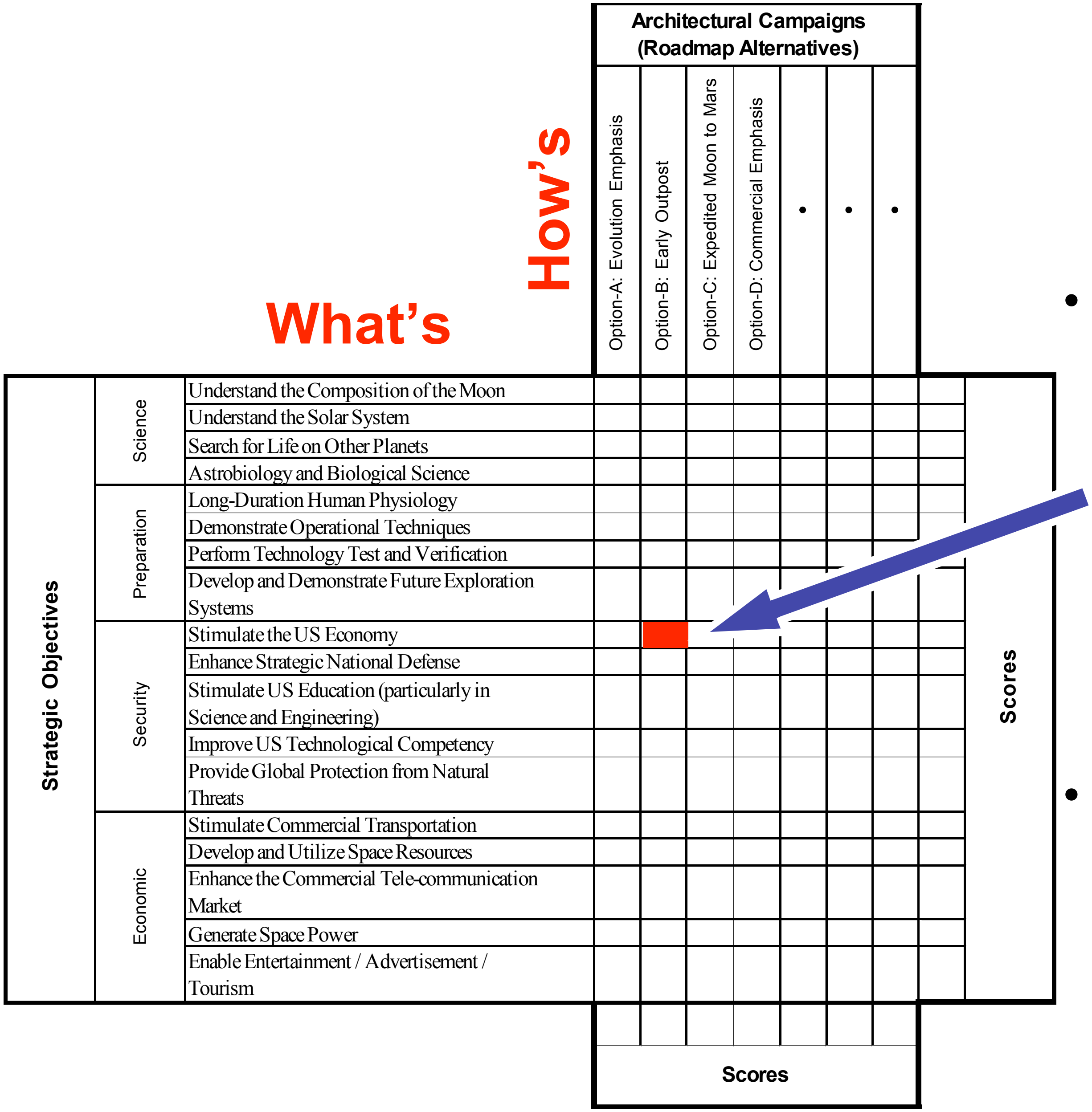
The Vision for Space Exploration

The Fundamental Goal of This Vision is to Advance U.S. **Scientific**, **Security**, and **Economic** Interest Through a Robust Space Exploration Program



- Implement a sustained and affordable human and robotic program to explore the solar system and beyond
- Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and
- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

Strategy to Task to Technology (STT) Matrix-A



- Each Level Describes a set of
  - **What's** to be accomplished versus
  - **How's** to accomplish the what's

- For example:

  To what extent does the architectural campaign

  Option B: Early Outpost

  make a direct contribution to achievement of the strategic objective

  Stimulate the US Economy?

- The process provides a good understanding of what the stakeholders need and want, what our strategies are, and how those strategies tie to the needs of the stakeholder

Mission Statement for Lunar Exploration

Conduct robotic and human lunar expeditions to:

1. Further science, and to
2. Test new exploration approaches, technologies, and systems that will enable future human exploration of Mars and other destination

Science Metrics

Science

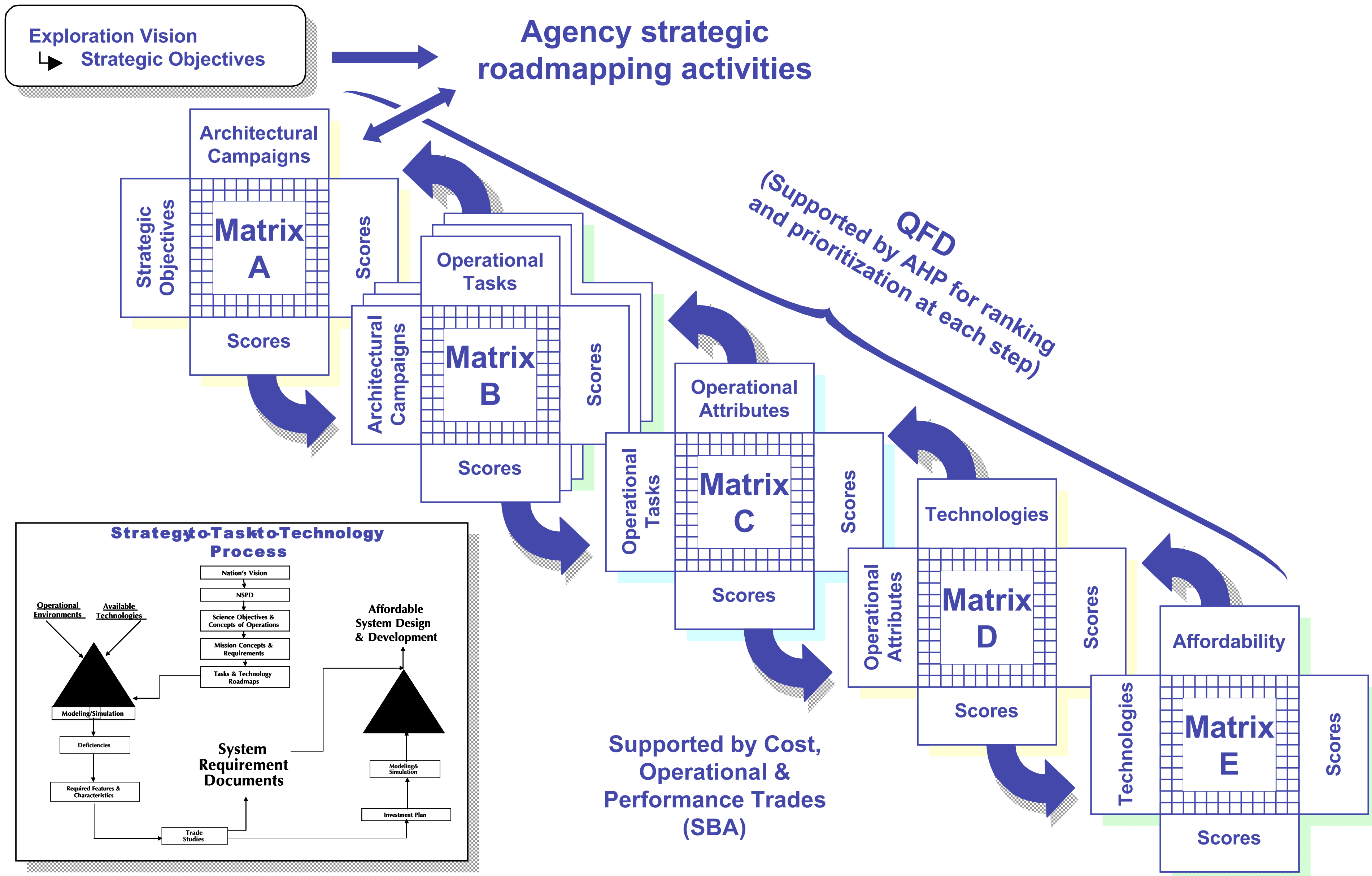
1	Investigate the origin and evolution of the Moon
2	Moon as a guide to other planets
3	Astrobiology
4	Human health and fundamental biology
5	Utilize the unique features of the Moon as a platform
6	Resource related science

Exploration Metrics

New approaches to support sustained human exploration to Mars and other destinations

1	Long-Duration Human Physiology
2	Demonstrate Operational Techniques
3	Perform Technology Test and Verification
4	Develop and Demonstrate and innovate future Mars Systems and subsystems
5	Demonstrate increased maintainability, reliability and supportability (ability to repair etc.)
6	Enable business opportunities
7	Develop and utilize Lunar resources and understand mapping to Mars
8	Enhance Strategic interests
9	Stimulate U.S. Education

Exploration Systems Quality Functional Deployment (QFD) Flowdown



Start of a Good Study

Testing Venue Descriptions

Ground-Based Testing

Laboratory: Basic laboratory testing of system components in a breadboard or relevant environment. Includes computer simulation testing. Low to mid-TRL (1-6) technology testing.

Integrated Physical Testing: Physical testing of integrated components in a relevant simulated environment. Includes testing of integrated systems and vehicles to validate the integrated performance of the "whole" . Low to mid-TRL (1-6) technology testing.

Field: Tests conducted in remote locations on the Earth that provide similar environments expected on planetary surfaces. Low to mid-TRL (1-6) technology testing.

Low-Earth / Near-Earth Testing

ISS: Includes testing conducted at the ISS in LEO. Both IVA and EVA tests are included. Mid to high-TRL (6-9) technology testing.

Near-Earth: Includes testing conducted in LEO, but not at ISS as well as testing conducted in Near-Earth space beyond LEO. Mid to high-TRL (6-9) technology testing.

Lunar Surface Testing

Robotic: Includes all testing conducted on unmanned lunar robotic missions. Generally considered small-scale missions with limited capabilities and resources. Mid to high-TRL (6-9) technology testing.

Short-Stay: Includes short-stay human missions to the surface of the moon. Missions generally last several days (3-7), include modest capabilities (power, volume), and provide moderate exploration ranges (EVA and rover range). Mid to high-TRL (6-9) technology testing.

Long-Stay: Includes longer stay human missions to the surface of the moon lasting months. Capabilities provided are significantly improved (power, volume) with the capability for repeated longer range field explorations. Mid to high-TRL (6-9) technology testing.

Mars Robotic

Small: Considered similar to today's mission capability with constrained surface delivery capabilities and resources. Mid to high-TRL (6-9) technology testing.

Large: Robotic missions much larger than those planned today with significantly greater capabilities. Missions which pre-deploy cargo for future human missions are included in this class. Mid to high-TRL (6-9) technology testing.

An Example (1 of 28): EVA Systems

Critical Elements to Test

- **Space suit mobility & dexterity performance**
- **EVA communications / information systems**
- **Life support system component operation**
- **Space suit thermal protection & operation**
- **Dust protection and radiation protection**
- **EVA traverse mapping & route planning**
- **Surface mobility systems "trafficability"**
- **EVA system maintenance strategies**

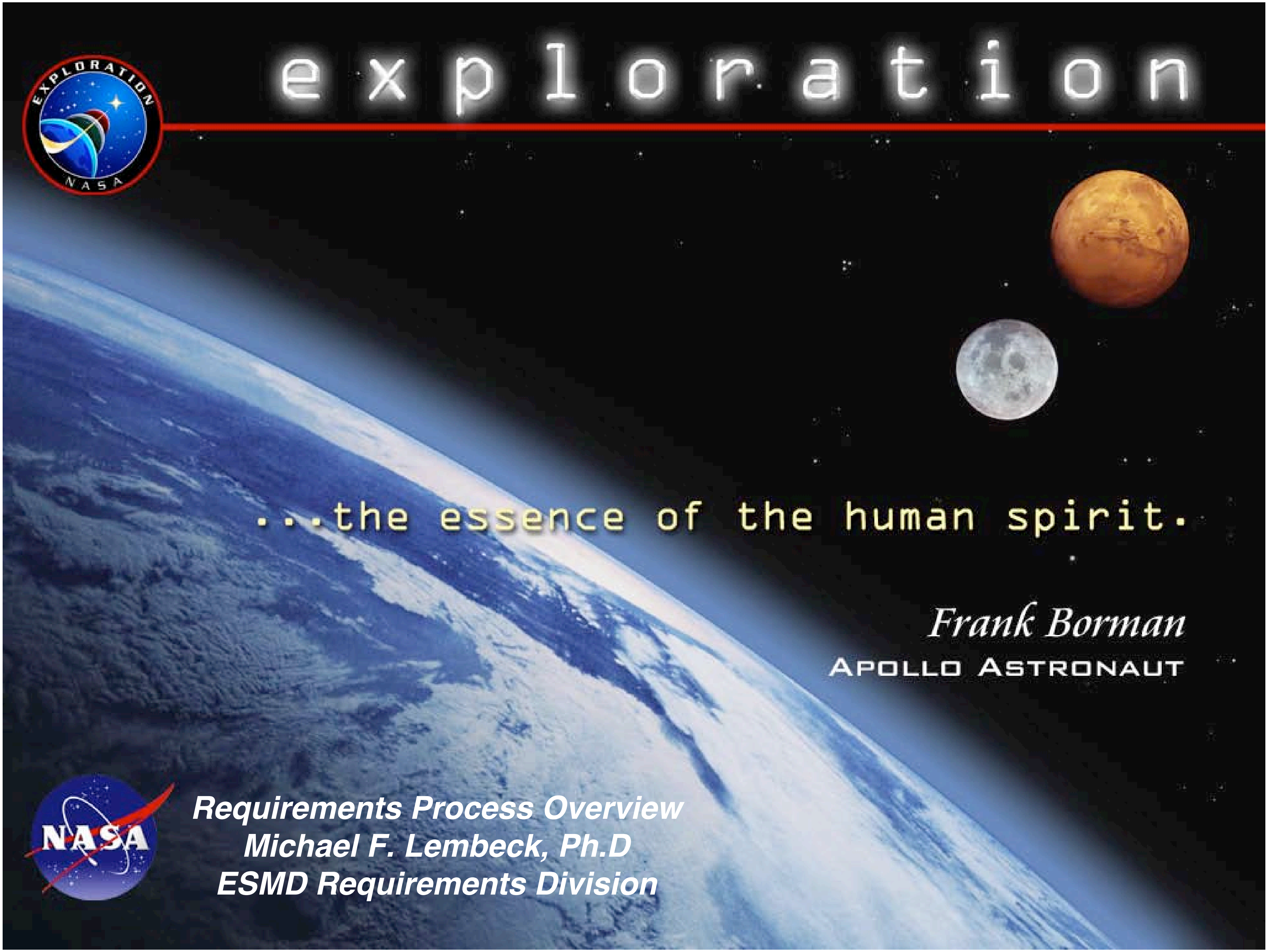
Testing Venues & Benefits

- **Earth-based facilities**
  - Certification in ground-based simulators required before use
  - Both simulators and field tests allow "build a little; test a little" to provide greater insight to "go/no go" technical decisions
- **Near-Earth Flight Tests**
  - None identified
- **Lunar Tests**
  - Lunar surface tests can establish EVA systems functional performance capabilities in a similar environment
  - May prove useful for long-term "dry run" rehearsals and "what if" scenarios
- **Mars Robotic Missions**
  - Key to providing martian environmental and hazard data

Testing Approach & Support Needed

- **Earth**
  - High-fidelity simulators and chambers
  - Analog ground-based (field) testing
  - KC-135 flight tests at various gravity levels
  - Integrated systems tests of leading candidates to "down-select"
- **Near-Earth**
  - No apparent benefits considering the vast operational and unique environmental differences between LEO and planetary surfaces.
- **Lunar**
  - Surface EVA in greater numbers & durations for system validation
  - Validate EVA traverse mapping & route planning techniques
  - Lunar surface conditions similar, but not truly "Mars-like"
- **Mars Robotic**
  - Mars robotic missions are key to providing martian environmental data (dust composition, thermal, radiation, terrain, hazards)

JSC/J. Kosmo, Trevino ARC/B. Webbon


exploration
...the essence of the human spirit.
Frank Borman
APOLLO ASTRONAUT
Requirements Process Overview
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